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METRIC AIDS FOR ESTIMATING RADIOACTIVITY LEVELS IN SURFACE WATERS FROM COUNTING DATA

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Applications and Development Report

No. 10

Metric Aids for Estimating Radioactivity Levels in Surface Waters from Counting Data

E. P. Floyd

Water Quality Section
Basic Data Branch
Division of Water Supply and Pollution Control
Public Health Service
Department of Health, Education, and Welfare

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May 1964

The Author

Mr. E. P. Floyd, Senior Health Service Officer, is In Charge of the Radioactivity Gross Screening program of the PHS Water Pollution Surveillance System. The metric aids described in this report were developed to provide immediate preliminary results on the levels of radioactivity which exist in the surface waters of the rivers and Great Lakes. These aids have been used in the Radioactivity Laboratory since May 1963.

Mr. John D. Weeks, Senior Sanitary Engineer, assisted in the development of the nomograms.

Leo Weaver, P.E.
Chief, Water Quality Section

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Metric Aids for Estimating Radioactivity Levels in Surface Waters from Counting Data

by

E. P. Floyd

Introduction

Since 1957 data on radioactivity levels in the surface waters of the United States have been gathered through the PHS Water Pollution Surveillance System.* Sampling points have been established in all major river basins and the Great Lakes. Sampling has been carried on jointly with State, Federal and local agencies, and industry. Measurement of suspended and dissolved radioactivity levels in these samples provides data for evaluating sources of radioactivity which may affect the legitimate uses of surface water, and provides background information essential for the detection of changes of levels of radiation in surface waters of the United States (Weaver, et al.).(1)

Beginning with the establishment of 50 sampling points in 1957 the PHS Water Pollution Surveillance System is now comprised of 130 stations at which one-liter samples of surface water are collected weekly for

* Formerly National Water Quality Network

radioactivity analyses.[2] These samples are usually received at the Surveillance System laboratory within the week following collection. Preparation of these samples and counting for gross alpha and gross beta activity requires another week to ten days. The instrument sample count, background count, aliquot size, weight of dried sample, and other pertinent information (referred to as raw data) are recorded and sent to Statistical Services for computation in order to get the calculated activities in picocuries per liter of original sample. Processing of these data, mailing time to and from another facility, punching and verifying cards, computation by electronic computer, and printing out the finished results requires another week to ten days. Thus, the obtaining of a final result may take as long as four weeks.

It is important that the time required for reporting results of special interest be minimal. When unusual alpha or beta activities are found and verified, "alerts" can be made rapidly without waiting for the time consuming delays associated with machine processing. In addition, quick judgments can be made regarding the validity of the raw data so that recounts or reruns can be made immediately when necessary without waiting the several weeks ordinarily consumed in processing.

The analytical procedure used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater."[3]

Nomogram for estimating gross beta activity

This nomogram (Figure 1) was developed to cover a range of values for suspended solids from 0 to 200 milligrams per planchet, dissolved solids from 0 to 2000 milligrams per planchet, and a sample aliquot volume range from 5 to 500 milliliters, each with an appropriately graduated scale. It is based on the following equation:

$$pc/l = \frac{(K_{Al})\ (CPM)}{V}$$

in which:

pc/l = picocuries per liter,

K_{Al} = combined self-absorption, backscatter, geometry, and disintegrations per minute to picocuries conversion factor for aluminum planchets (determined experimentally on internal proportional counting equipment)[4] (Figures 2 and 3),

CPM = net counts per minute,

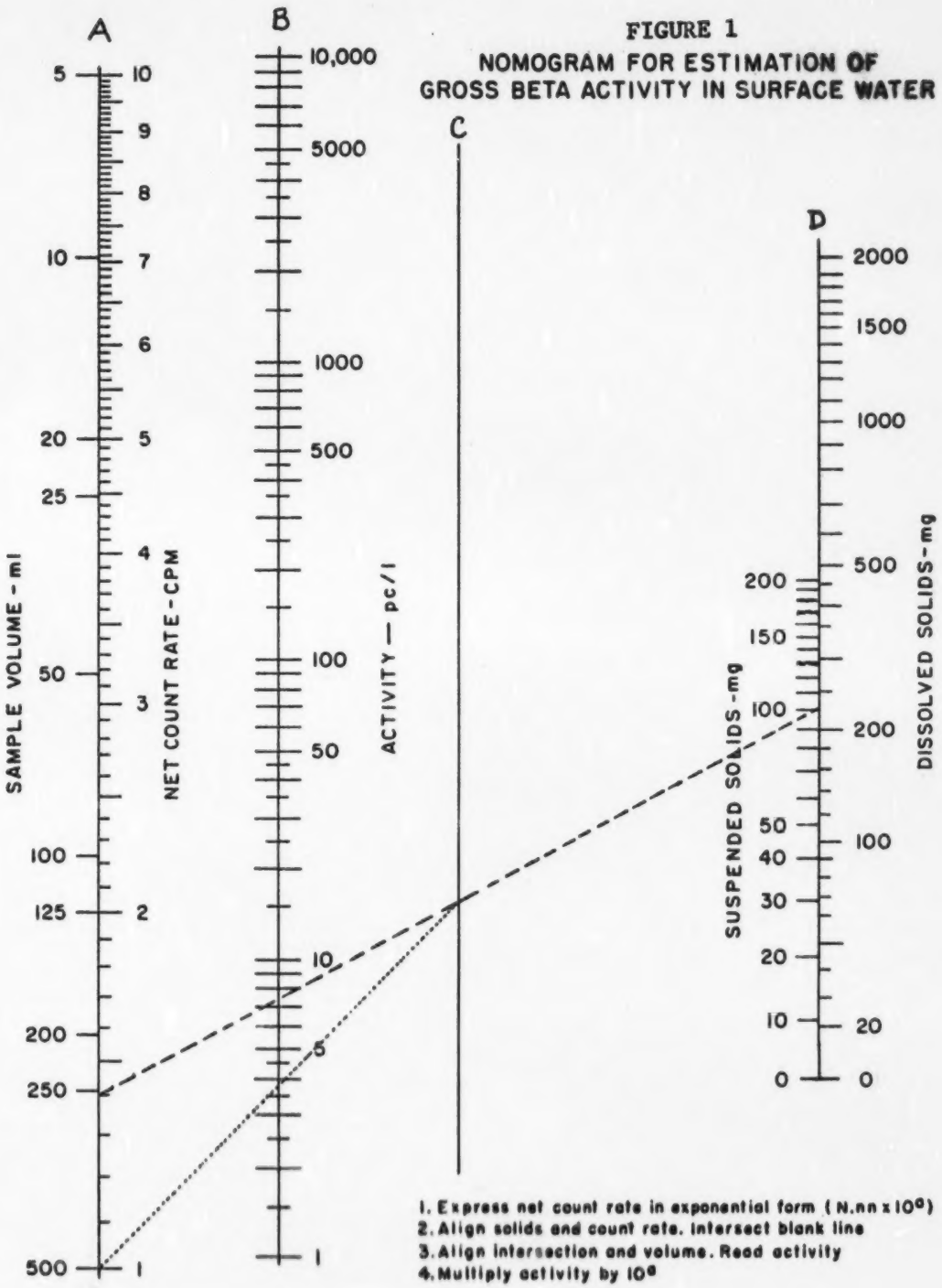
V = sample aliquot volume in milliliters.

The construction of this nomogram consisted of the drawing of four parallel lines, A, B, C, and D in Figure 4 so that C is equidistant from A and D, and B is equidistant from A and C. All scales are logarithmic (1, 2, or 4 cycle) and arranged so that a point on the A scale (right) aligned with a point on the D scale intersects C at a point equal to the product of the represented points of K_{Al} and CPM. This point on line C represents the numerator in the equation. A point on the A scale (left) represents the denominator. The point on line C aligned with the point on the A scale (left) is the value in picocuries per liter.

In its final form (Figure 1) the residual weights for suspended solids (D scale, left) and for dissolved solids (D scale, right) were substituted for their respective K_{A1} values (Figures 2 and 3).

An example of the use of this nomogram is given in Figure 1 for a 500 ml water sample in which the weight of the suspended solid residue was 100 mg and the net CPM was 14. Following the specific directions given on Figure 1, the final estimate is 38 picocuries per liter of original sample. (Note: $1.4 \times 10^1 = 14$; $3.8 \times 10^1 = 38$)

FIGURE 1
NOMOGRAM FOR ESTIMATION OF
GROSS BETA ACTIVITY IN SURFACE WATER



1. Express net count rate in exponential form (N.nn x 10^{e})
2. Align solids and count rate. Intersect blank line
3. Align intersection and volume. Read activity
4. Multiply activity by 10^{e}

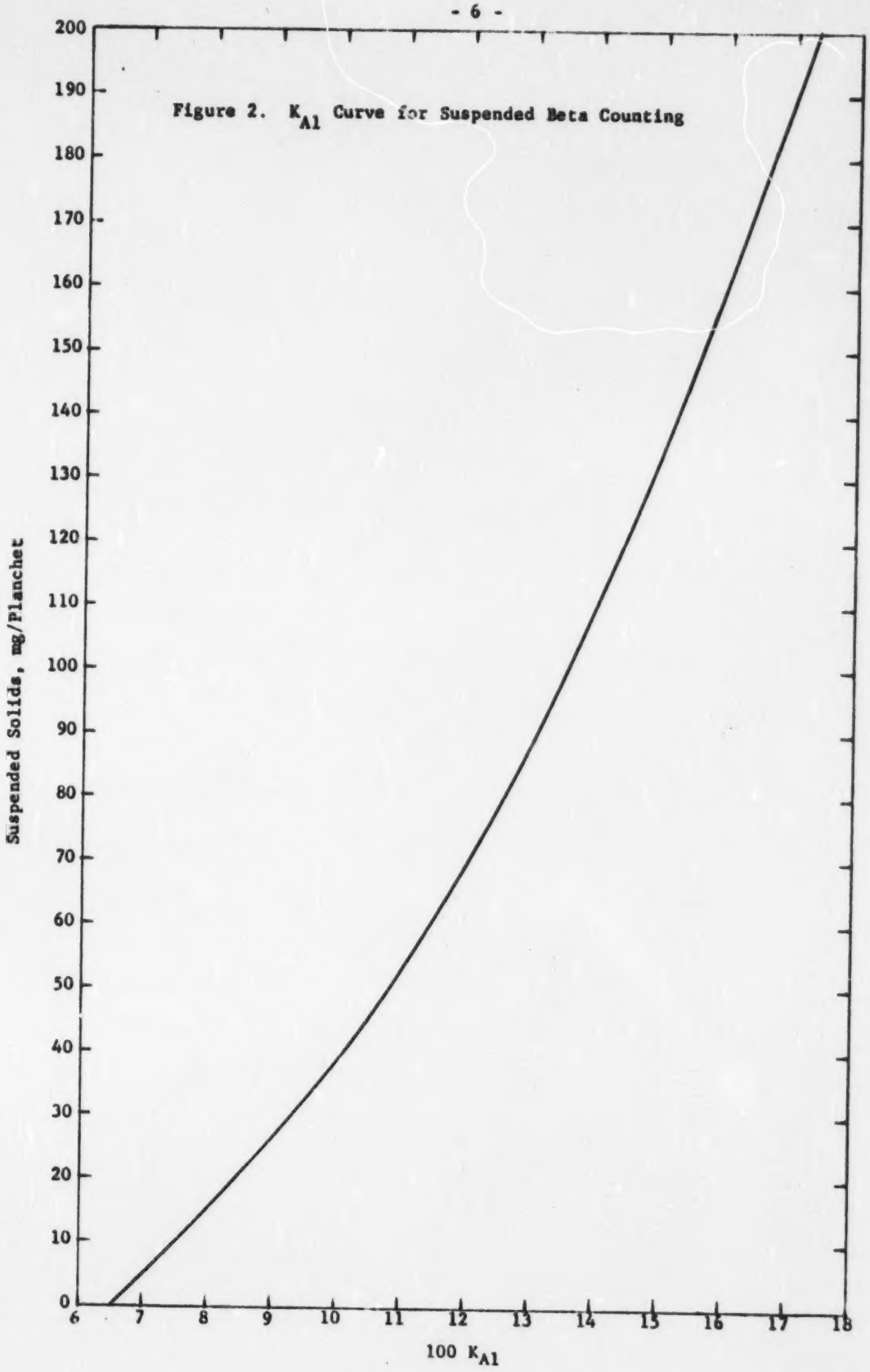


Figure 2. K_{A1} Curve for Suspended Beta Counting

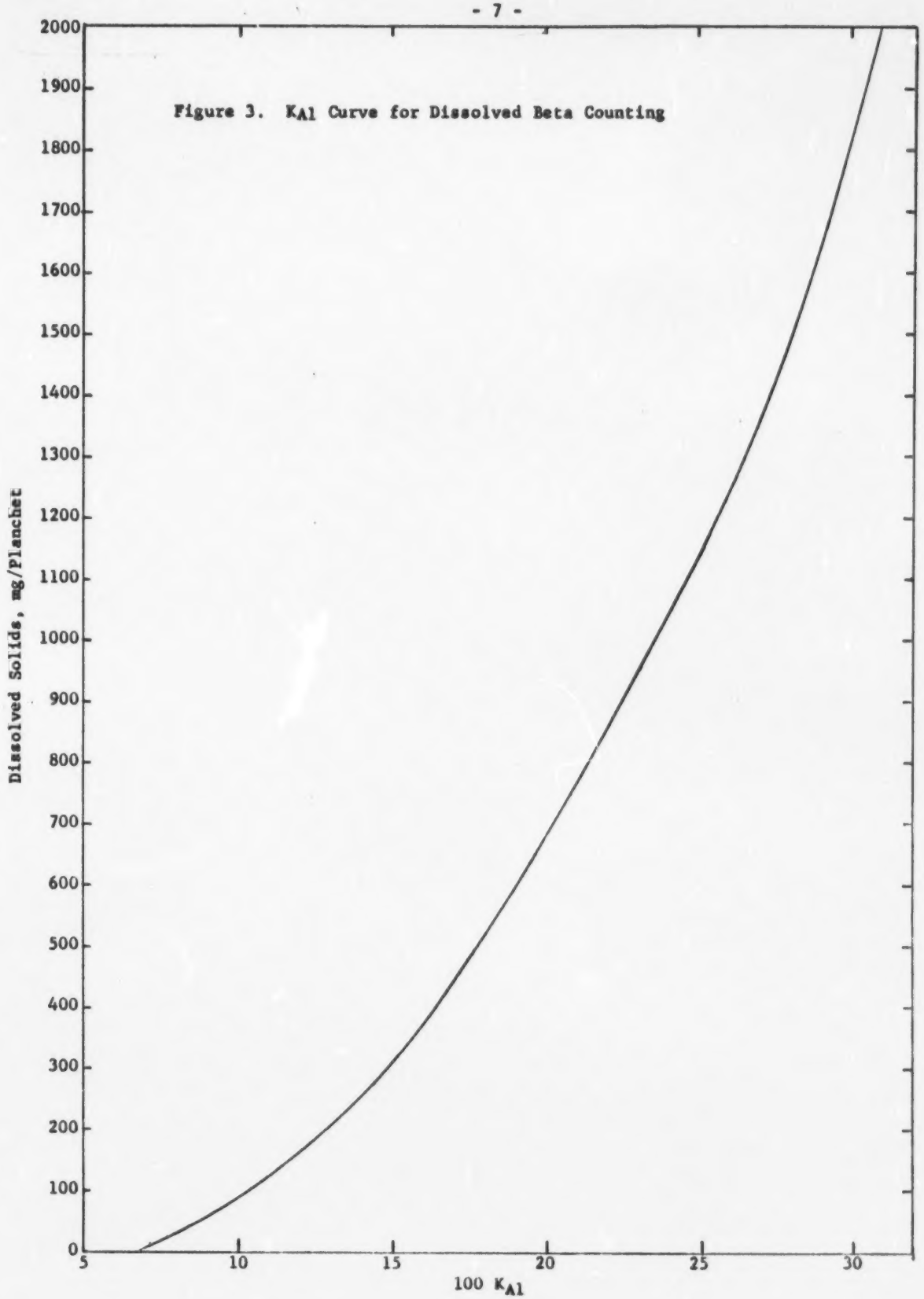
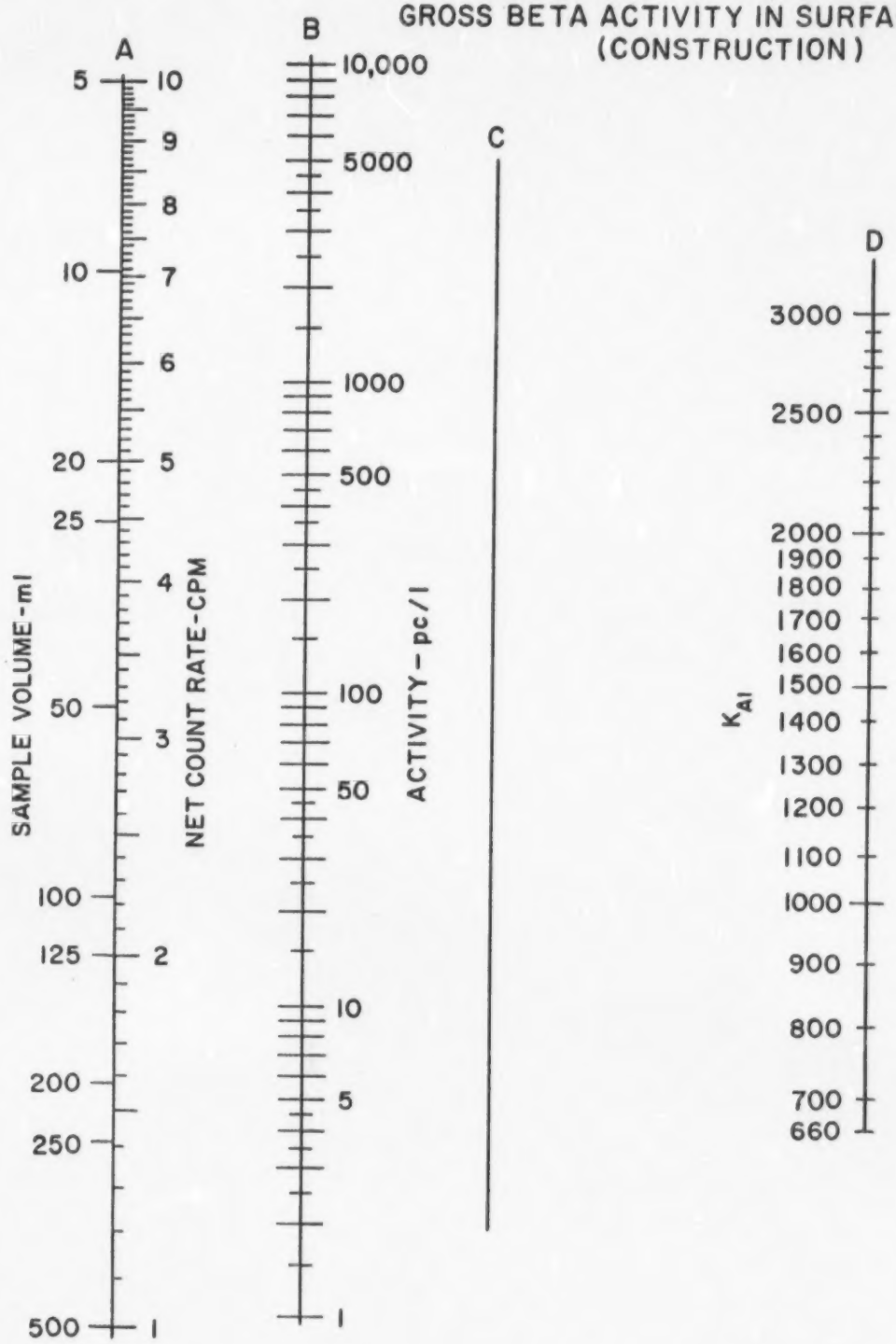


Figure 3. K_{A1} Curve for Dissolved Beta Counting

FIGURE 4

NOMOGRAM FOR ESTIMATION OF GROSS BETA ACTIVITY IN SURFACE WATER (CONSTRUCTION)



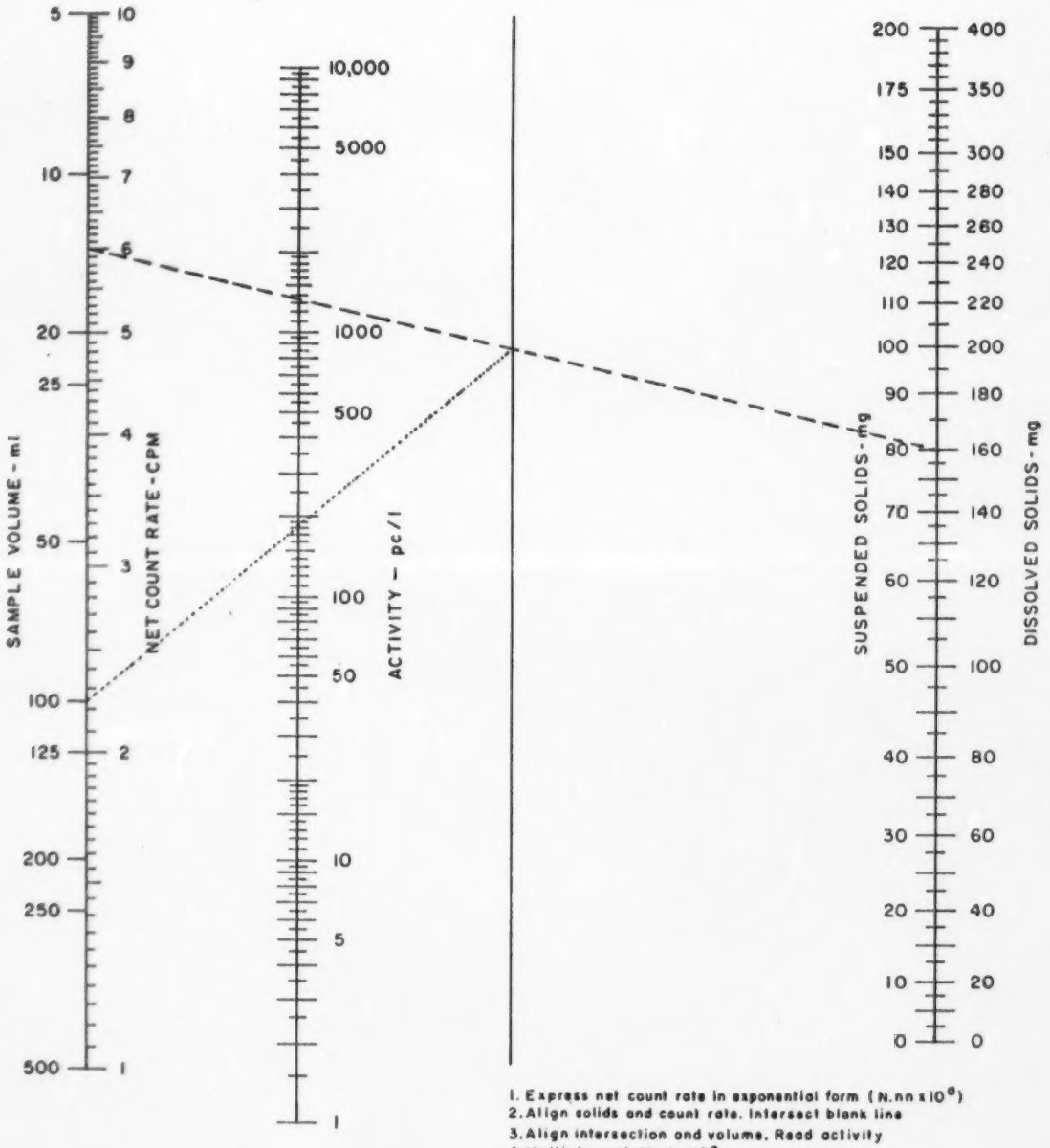
Nomogram for estimating gross alpha activity

This nomogram (Figure 5) is designed to cover a range of values for suspended solids from 0 to 200 milligrams per planchet, dissolved solids from 0 to 400 milligrams per planchet, and a sample aliquot volume range from 5 to 500 milliliters, each with an appropriately graduated scale. It is based on the same equation used for calculating beta activity, but with necessarily different K_{A1} factors (Figure 6). The construction of this nomogram is identical in steps to the one for estimating gross beta activity.

An example of the use of this nomogram is given in Figure 5 in which the sample aliquot was 100 ml, the dissolved solid residue weighed 160 mg and the net CPM was 0.6 CPM. Following the directions given on Figure 5 the estimate of dissolved gross alpha activity is 18 picocuries per liter of original sample. (Note: $6 \times 10^{-1} = 0.6$ and $180 \times 10^{-1} = 18$)

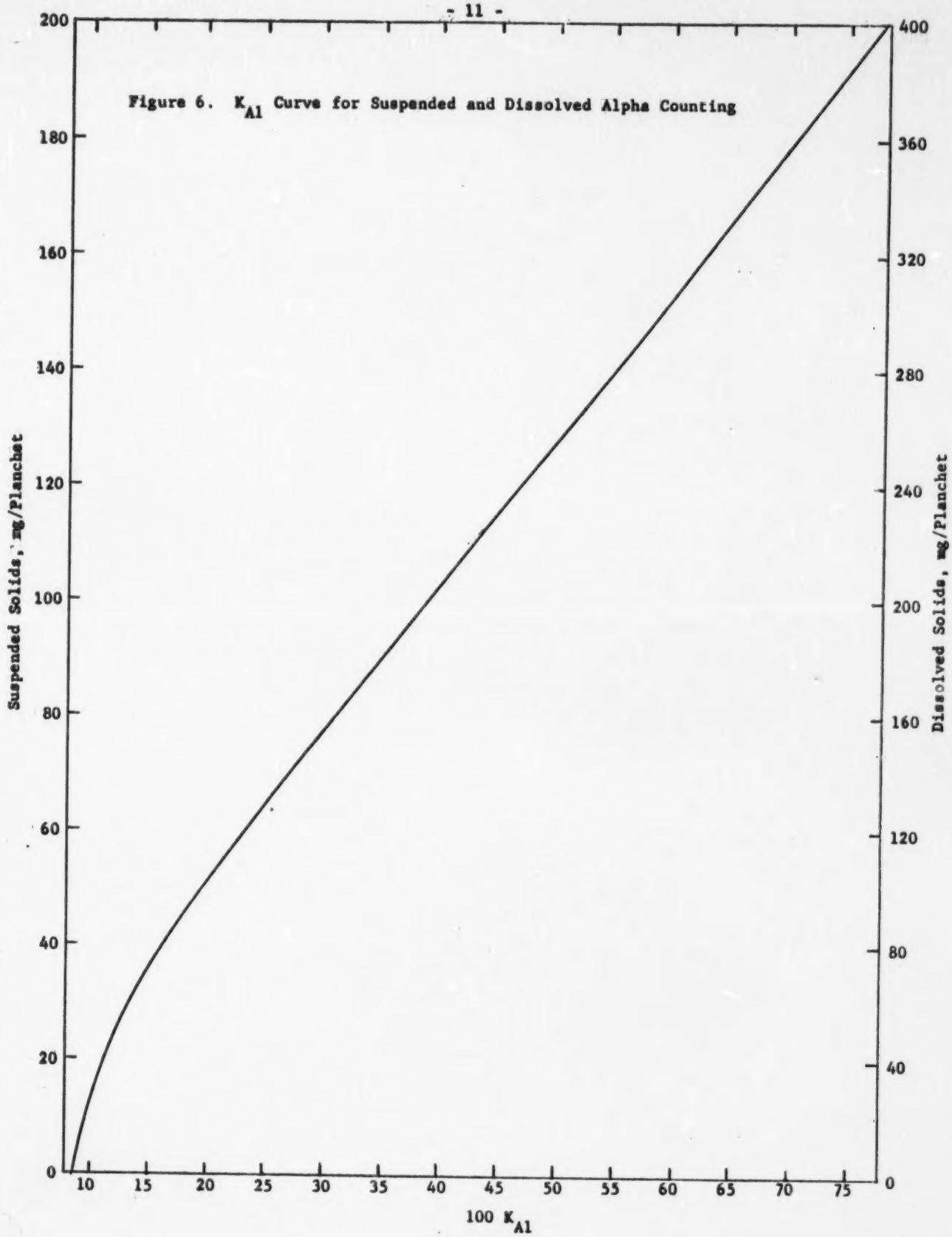
FIGURE 5

NOMOGRAM FOR ESTIMATION OF GROSS ALPHA ACTIVITY IN SURFACE WATER



1. Express net count rate in exponential form ($N.nn \times 10^{6}$)
2. Align solids and count rate. Intersect blank line
3. Align intersection and volume. Read activity
4. Multiply activity by 10^{6}

Figure 6. K_{Al} Curve for Suspended and Dissolved Alpha Counting



Nomograms for estimating statistical counting errors

Two nomograms were developed to fit the needs of the Surveillance System's most frequently used total count times (20 minutes and 60 minutes) for samples and backgrounds run on automatic counters with a 50 planchet capacity column. Samples run overnight are counted for 20 minutes each, and those run over the weekend for 60 minutes each. Only on a rare occasion is a different count time used.

These nomograms (Figures 7 and 8) are of the three parallel line type using arithmetic scales for both the gross count and the background count. The intersection scales on either side of the center line were constructed to comply with the equation for the 95% confidence level:[5]

$$CPM_E = 1.96 \sqrt{\frac{CPM_s}{T_s} + \frac{CPM_b}{T_b}}$$

in which:

CPM_E = the counting error in counts per minute,

CPM_s = the gross sample count in counts per minute,

CPM_b = the background count in counts per minute,

T_s = the sample total count time in minutes,

T_b = the background total count time in minutes.

The useful range for these nomograms was extended by use of the appropriate factors indicated (0.1, 1.0, 10, 100), the outer factor on the nomogram being applied to both outside lines and the inner, associated, factor being applied to the center line on the same side with the factor.

To convert this counting error into pc/l this CPM_E value must be used with the appropriate nomogram to match it with the proper sample in the same manner that the gross activity of the sample was calculated.

Examples of the use of these two nomograms are given in Figures 7 and 8. In Figure 7 the gross count of 42.0 CPM and the background count of 28.0 CPM are illustrated (dashed line). In this case the pair of factors, X10 ⟷ X10 is used, which means that the two outer scales are multiplied by 10 (i.e. 4.2 x 10 = 42, and 2.8 x 10 = 28) and the scale to the right of center is also multiplied by 10 (i.e. 0.365 x 10 = 3.65). The answer is 3.65 CPM, which is the error in counts per minute. To convert this to picocuries this value must be applied to the nomogram in the same manner as the net CPM was applied.

Had these values been 420.0 CPM (gross) and 28.0 CPM (background) then the dotted line serves as the illustration and the factor pair would be X100 ⟷ X10 on the nomogram. In this case the answer is 9.25 CPM. Both of these examples are based on a total count time of 20 minutes.

In Figure 8 another example is given (based on 60 minutes count time) for a gross count of 0.8 CPM and background of 0.2 CPM (dashed line). In this case the factor pair is X1.0 ⟷ X0.1 which gives a counting error of 0.25 CPM.

FIGURE 7

NOMOGRAM FOR ESTIMATION OF
COUNTING ERROR FOR 20 MINUTES
COUNTING TIME

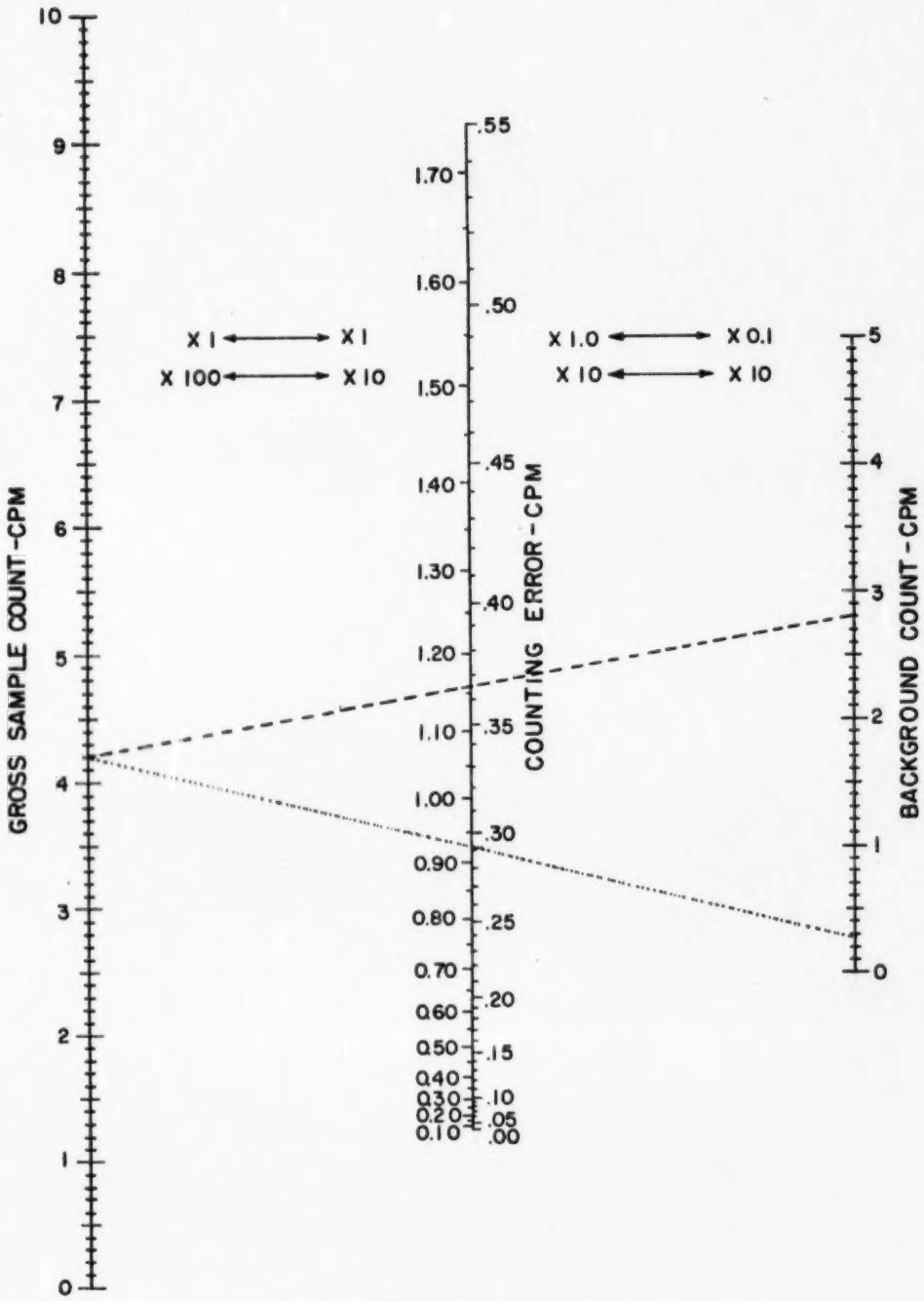
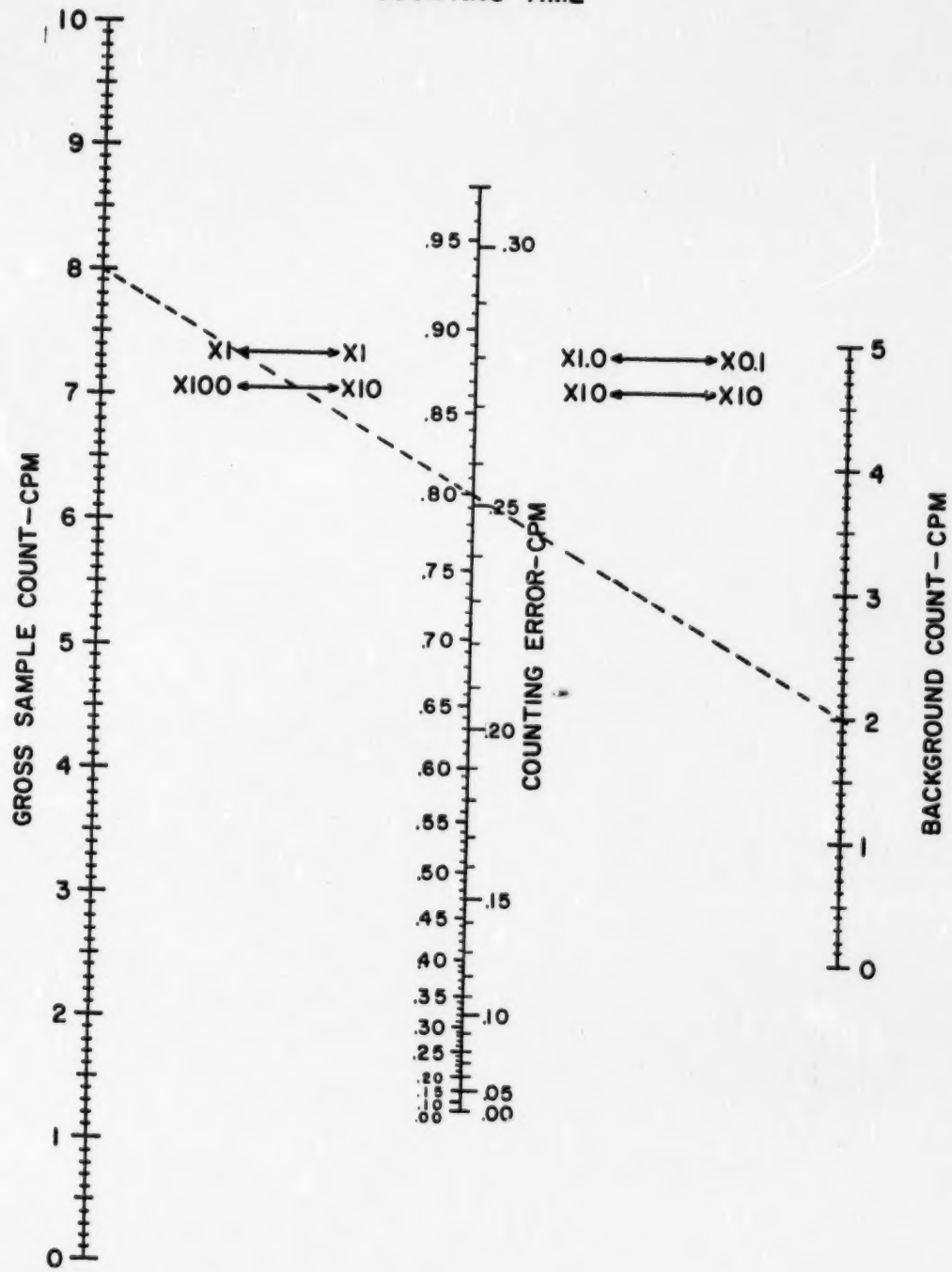


FIGURE 8

NOMOGRAM FOR ESTIMATION OF
COUNTING ERROR FOR 60 MINUTES
COUNTING TIME



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